

Application of Remote Sensing Technology for Studying Littoral Sediment Dynamics

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ABSTRACT

Satellite remote sensing data pertaining to two areas, one each on east and west coasts of India has been utilized to study suspended sediment dynamics within the near-shore region. For this purpose, thematic mapper image and second principal component image were used for area 'A' and 'B' respectively. The behaviour of sediment laden plumes was examined in detail to understand the distribution and dispersion of suspended sediments. Based on tonal and textural variation, five distinct types of turbid water masses have been identified in area 'A' and four in area 'B'. It is concluded that: (1) the currents of the study areas are influenced mainly by riverine discharge and shoreline configuration, (2) littoral sediments are transported in southwest direction in area 'A' and in southeast direction in area 'B', and (3) qualitative estimates of suspended sediments and their movements can be well studied with the help of satellite remote sensing technology. Thus, the present study demonstrates the capability of remote sensing technology in determining littoral sediment dynamics correctly, economically, less laboriously and in a short time.

INTRODUCTION

Though the capability of satellite remote sensing technology, which provides a periodic, integrated and synoptic view, has been utilized extensively in land studies in India, less attention has been paid to study nearshore region. During the last few years, qualitative analyses of suspended sediment distribution, dispersion of turbid water, littoral processes, shoreline changes and detection of waves, currents and net shore drift have been attempted by different workers [2-9].

Wave action is the primary source of energy available in the nearshore zones for various processes responsible for sediment motion along any open coast. One of the important effects of the littoral current produced by wave energy is the movement of sediments as littoral drift along the coast. This littoral drift, along with suspended sediments discharged by rivers, at their confluence with sea, develops a complex turbidity pattern in nearshore waters. This dynamics of littoral

sediments represented as turbidity patterns is very distinctly seen on the satellite images. In this study, employing remote sensing technology, an attempt has been made to understand littoral sediment dynamics by studying variation, dispersion, distribution and movements of turbid water masses in nearshore areas.

STUDY AREA

Two areas, one each on east and west coasts of India were preferred for this study, as they are located in two different physiographic, climatic and oceanographic environments. The study area 'A' (Fig.1) consisting of a long coast of about 320 km is located along the central east coast of India in Andhra state. The coastline is of emergent nature [1], with a narrow shelf. The area is dominated by two crescent shaped bays separated by prograded Krishna river delta. The onshore area is almost flat (gradient less than 10°) and is devoid of headlands and offshore islands.

The study area 'B' (Fig.2) consists of coast of Goa state along the central west coast of India. This coast is partly submergent and partly emergent in nature [10]

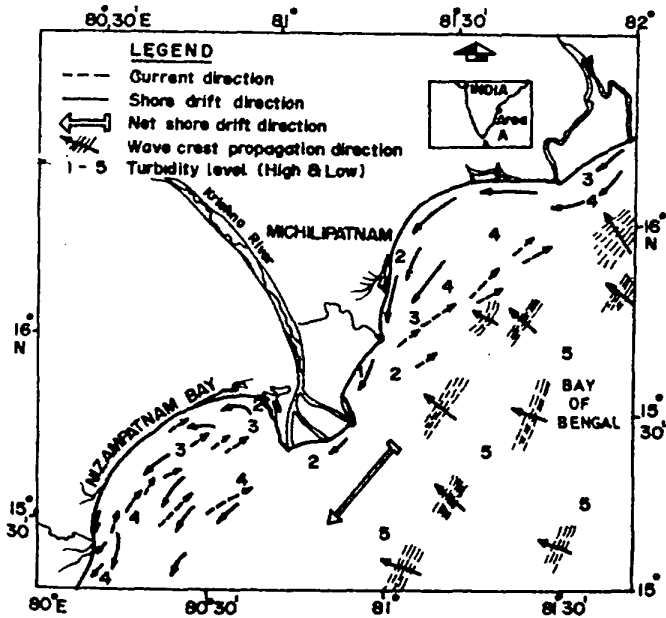


Fig.1 — Overlay of landsat thematic mapper image of area 'A' showing suspended sediment dispersion

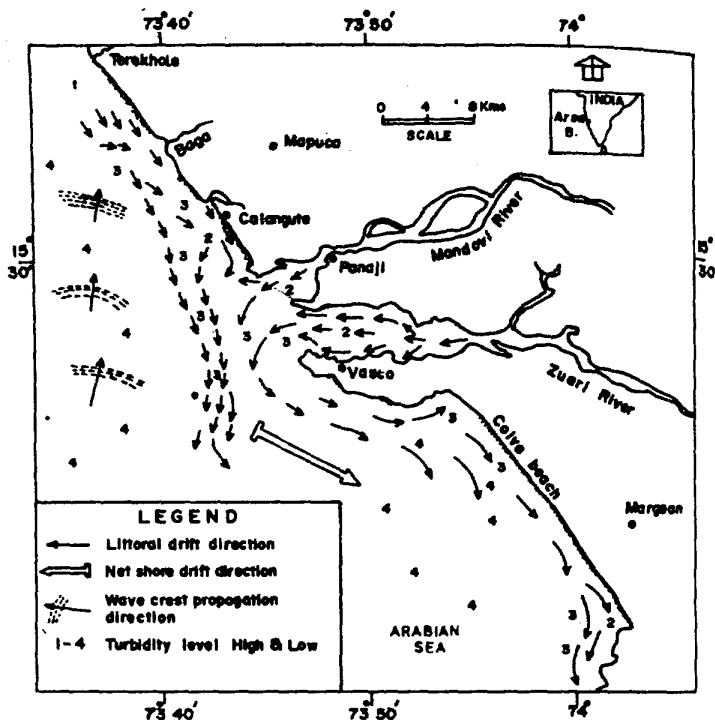


Fig.2 — Overlay of landsat MSS image of area 'B' showing suspended sediment dispersion

with a comparatively wider shelf. The coastal segment of about 105 km is constituted by alternately situated headlands, estuaries, bays and beaches. The region, being in the tropics, enjoys a warm, equable and humid climate. This area receives much of rainfall, about 3000 mm, during southwestern monsoon season (from June to September).

The predominant and durable wave generating winds are NW and SE monsoons over both the areas. They are generating coastal currents and shore drifts. In study area 'A', these winds are striking the shore obliquely, whereas in study area 'B', they are striking normally. The length of fetch for monsoon affecting areas 'A' and 'B' is about 1500 and 3000 km respectively.

MATERIALS AND METHODS

Thematic mapper (TM) imageries in 5 spectral bands (TM 1-5) pertaining to scene D142-049, dated 17 March 1985, of Landsat 5 were collectively examined

to understand the sediment movements of area 'A'. In the case of area 'B', Landsat images are providing little information about the nearshore region. As the influence of oceanic features on each band is highly correlatable, the compression of all bands into a single plane helps in better recognition of oceanic features. For this purpose, principal component transformation was performed by digital processing of 4 bands of Landsat 5 multi-spectral sensors data (Path 49, Row 142, dated 31 March 1986) and four principal component images were produced. The second principal component (PC 2) image was found most suitable for studying area 'B' (Fig.3). These photographic and digital products have been studied in detail. Qualitative turbidity variation and turbid water movements have been monitored and are presented in Figs 1 and 2. Digital processing was carried out on DIPIX image processing system working under VMS operating environment.

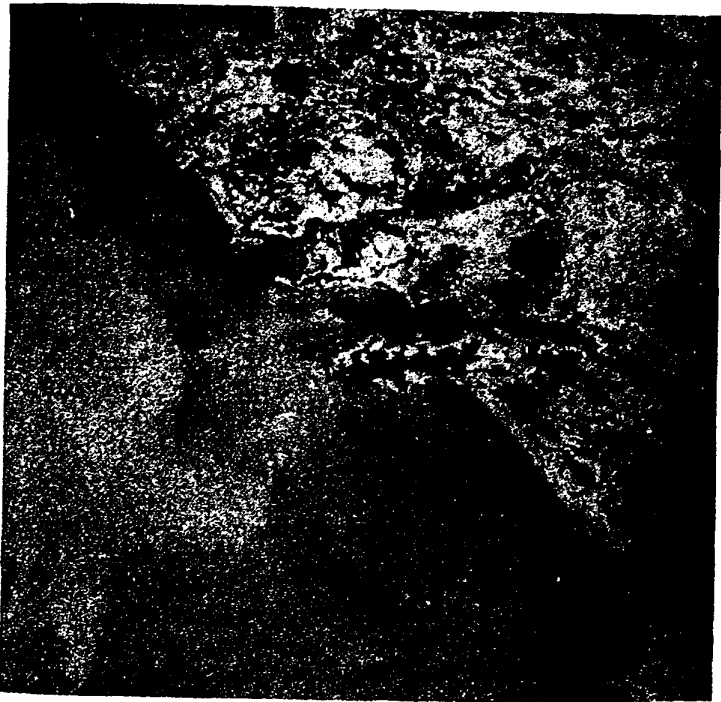


Fig.3 — Second principal component image of area 'B' showing turbid water movements

DISCUSSION

Satellite images provide a synoptic view of discrete turbid water masses in the nearshore region. Depending on the type of particulate matter, stratification, depth of settling and bottom conditions, the turbid waters will be more reflective than clear water and will appear in different shades of gray tones based on turbidity. On satellite images, the sharp contrast between various sediment laden water is clear and mappable. Tonal variation is considered as a measure of turbidity concentration. Texture and pattern help in monitoring distribution and movements of turbid water masses.

Suspended sediment distribution — Based on tonal and textural variations, five distinct types of water masses are identified qualitatively in area 'A': (1) highly turbid water, (2) moderately high turbid water, (3) turbid water, (4) less turbid water, and (5) almost clear water. In area 'B', four types of turbidity levels are identified: (1) highly turbid water, (2) turbid water, (3) less turbid waters (4) almost clear water. These are evidently related to the concentration of suspended sediments. Overall, the higher concentration was in the highly turbid water, followed by turbid water and minimal in clear water. These water masses have been carefully studied for their tonal variation and mapped (Figs 1 and 2).

It is observed in area 'A' that, highly turbid water masses are seen off Krishna delta, north of delta and in near coastal areas of both Machilipatnam and Nizamapatnam bays. Tonal variation in Nizamapatnam bay indicates high to low gradation in turbidity from NE of bay towards SW. Almost uniform, moderate to high turbid water band is seen encircling the delta towards seaward side. A moderately high to high turbid water masses are located in the nearshore area, covering more area of south Machilipatnam bay than to north. In general, turbidity is seen reducing towards seaward side.

In area 'B', highly turbid water off Terekhol coast indicates that active erosion and deposition of sediments along this coast is in progress. From the diffused tonal and textural pattern it is further interpreted that sediments transported may contain clay particles which remain in suspension for a long period. River sediment discharge and deposition along coast is exhibited by the pattern of turbid waters observed off Calangute beach, within Mandovi and Zuari bays and at the confluence of Sal river. Turbid water masses are concentrated in the central portion of Zuari bay, whereas dispersed suspended sediments are observed on seaward side of Mandovi bay. Almost clear water is seen off Colva beach, whereas little turbidity is seen very near to the coast. This is probably due to an almost straight coastal track, absence of sediment discharging rivers and blocking of long shore currents due to Mormugoa headland, which is situated in the north of this beach. This area, being a protected zone, favours deposition of the sediments.

Currents — On satellite images, current directions are indicated by the sediment laden plumes as they become elongated and pointed in the direction of flow [3,6]. Thus, the current directions of the areas are approximately marked by

directed arrows based on the shapes of the plumes. In study area 'A', turbid water plumes near Machilipatnam coast and north of it indicate current direction as towards south (Fig.1). In SW part of the bay, these plumes are bending and show elongation and pointed ends towards NE. This pattern indicates the development of eddy due to currents. Presence of narrow, elongated and uniform turbid water plumes off Krishna delta are indicative of strong coastal currents from NE of delta towards SW.

Sediment plumes in NE bay are seen bifurcating into pointed finger-shaped plumes, pointing SW-wards. These finger-like plumes have indentations on southern margin, while the northern margin is plain and curved. The plumes are seen slowly diminishing towards SW. This plume pattern indicates that the coastal currents are towards SW and these currents are opposed by local currents developed probably due to bottom topography.

In area 'B', the currents are mainly influenced by river discharge. In the region off Mandovi and Zuari estuary, the plumes are noticed to travel along west and then towards south and SE direction (Fig.2). Of Sal, Baga and Terekhol river mouth, the plumes are seen dispersed, but are moving towards south. Less turbid waters have exhibited a near circular pattern in current borne sediments off Marmugao. Long shore currents, which are unable to bend around Marmugao headland, dissipate a greater part of their energy in a large eddy, which is exhibited by the near circular pattern of less turbid water. Another eddy pattern was also noticed off Baga river mouth.

Deep sea waves — Close observation of the imageries shows that parallelly arranged alternate gray and dark curvi-linear bands are located over the deep sea region. This pattern is interpreted as deep sea ocean waves. Direction of the propagated waves and their locations are marked on maps. In study area 'A', waves were seen approaching from SE direction and in area 'B' from SW before reaching to the coast.

Based on the direction of propagation of waves, tonal variation, dispersion pattern of the sediment laden plumes, local current direction, littoral sediment transport direction during the month of March is determined as towards SW in area 'A' and towards south in area 'B'. Landform indicators study [4] pertaining to area 'A' suggested that shore drift direction is towards SW direction during NE monsoon period. Landform indicators, like stream mouth diversion, spit growth, recession of cliff, beach width, mid-bay bar and tombolo of area 'b', when studied [5] suggested that the net shore drift of the area is towards south. Thus, these two studies confirm the findings of the present study.

CONCLUSION

The conclusions emerging from the present study are: (1) The currents of the study areas are influenced mainly by riverine discharge and shoreline configuration (2) Littoral sediments are transported towards southwest direction in area 'A'

and towards southeast in Area 'B'. (3) Qualitative estimates of suspended sediments and their movements can be well studied with the help of satellite remote sensing technology. Thus, the present study demonstrates the capability of remote sensing technology in determining littoral sediment dynamics correctly, economically, less laboriously and in a short time.

ACKNOWLEDGEMENT

The authors offer their thanks to Dr. B.N. Desai, Director, for permission to publish this material. They are thankful to Dr. R.M.S. Bhargava, Head, Data and Information Division, Mr. R.R. Nair, Head, Geological Oceanographic Division and Dr L.V.G.Rao for the encouragement provided.

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